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face is worked out for Iceland spar. Here it is shown how a ray may fall obliquely upon a plane surface without suffering refraction. Here too is set forth the invention of the ellipsoidal wave surface to explain refraction in uniaxial crystals—one of the cleverest chapters in the entire history of science. The sixth chapter is given over to “the figures of transparent bodies which serve for refraction and for reflection.” Here the principle of “equivalent optical paths” is employed with its well-known elegance. The thanks of all students of optics are due to both translator and publisher for this complete and accurate rendition of a memoir which has long been so rare and expensive as to be practically out of reach of the ordinary reader.

H. C.

SPECIAL ARTICLES

THE HISTORY OF LOST RIVER

IN a previous paper written over a year ago and published by the Society for Protection of New Hampshire Forests, in their annual report for 1911, I tried to solve the problem which Lost River presents. Since that time I have made several visits to Kinsman Notch and have each time found new evidence on which to base conclusions. The following paper is offered as a further attempt at an explanation, based on the new evidence.

Lost River is a small stream rising in Kinsman Notch, about seven miles in a westerly direction from North Woodstock, New Hampshire.

The spectacle which presents itself on entering the river is very confusing. The river is immediately lost to view among a mass of huge granite blocks, some of them as large as average dwelling houses. Large potholes are numerous, as well as many beautifully curved water channels. Many of the potholes are fractured and fragments of these lie in the general mass. By careful inspection it is seen that this is an old rock gorge, and that something violent has taken place. Many joint blocks have fallen in, making it impossible to follow the water of the river in its course without ladders and bridges. The Society for

Protection of New Hampshire Forests, has purchased 148 acres, including the Lost River and the overhanging cliff, and has placed ladders and bridges in the gorge, so it is no longer difficult to see all the interesting points. There are two sets of caverns (so called because of large vacant spaces between the joint blocks), an upper and a lower. The upper caverns are about one quarter of a mile long. The stream emerges from these at Paradise Falls, flows unobstructed for about 150 feet, and plunges again beneath another mass of joint blocks, the lower caverns. The latter are not so imposing nor as extensive, although very interesting.

In contemplating this heap of granite blocks with the purpose of finding an explanation to the riddle, there are three agents which present themselves as seemingly capable of bringing about such confusion: frost action on a large scale; the disruptive force of a moving glacier; and earthquake action.

There has been considerable frost action in the gorge, and without doubt many blocks have been slowly wedged apart and fallen down from the sides of the gorge. That frost action, however, does not account for all the falling and movement, is to me quite evident. When in the lowest caverns one finds cases where blocks which have slipped from between other huge blocks in place, have left the upper and lower blocks entirely unmoved in the solid ledge. Smooth slickenside-like patches give evidence of a rapid and violent movement. This does not resemble frost action. The fearful confusion and pell-mell attitude of the mass also bespeak something more than the gradual work of frost.

The disruptive force of a moving glacier would seem at first glance capable of creating such a confused mass of joint blocks. It could not account, however, for the movements below the solid ledge, as described above. In one case I found a movement in a lateral direction between two blocks. The lower one is evidently in place and a part of the solid ledge, and the upper one has moved against the direction of movement of the ice about four inches. If ice were accountable for the slip,

surely the lower block could not have been moved, and the upper block would not have moved contrary to the ice motion. If the slipping can be explained by frost action, the positions of the other blocks can not, for they have evidently been thrown about by some other force. Furthermore if moving ice caused the confusion, one would naturally expect to find several different kinds of rock in the gorge. As far as I have explored the river one kind of rock only is present, a rather coarse biotite granite. A dark schist occurs in Beaver Meadows and some fragments of this should be found in Lost River only half a mile away. In the true moraines 100 yards away to the south, abundant fragments of this schist are found, but nothing of the kind in Lost River.

The fact that many of the potholes are cracked, disrupted and weathered as deeply as rocks outside of the gorge makes it evident that most of the potholes were formed before the main force which caused the confusion came. In any event most of the potholes were formed when the river had much more sediment than at present, and presumably this was during Glacial Period times, or at least when the ice had not retreated wholly from Kinsman Notch. The present amount of flow of very clear water is too small to account for the larger potholes. The largest of all is about twenty-five feet in diameter, narrowing toward the top. It has been badly broken and about one half only remains in position.

From the extraordinary positions of some of the water-worn channels it seems possible that much of the water work was done subglacially, although there is no proof as yet that such was the case. The main movement of the great ice sheet was south about 6° west, while Kinsman Notch at Lost River runs nearly east and west. It is probable that the ice in Lost River was nearly stationary during the height of glaciation, and that the main body passed over it with a shearing motion toward the south. The drainage under the ice would follow the present natural slope.

A study of the ground between Lost River and the cliff to the north helps to an under-

standing of what has probably taken place in the river. The way is difficult and somewhat dangerous. Huge blocks of granite are met with at once. They are piled in a pell-mell manner. As one ascends the blocks become somewhat smaller. There has undoubtedly been a large rock fall and one which immediately suggests a heavy earth shock as the starting force. Gradual weathering and falling would not account for the manner in which the rocks are wedged together. Weathering on all the large blocks of the rock fall, and on those in the river, has gone, as far as I can judge, to the same extent. From this fact it is also natural to conclude that the fall was of a sudden nature and not gradual. If the blocks had fallen one by one, weathering should have progressed to very different extents in different blocks. The granite of the cliff and that in Lost River is the same. There are no traces of any rock but the local granite in the rock fall, so this immediately does away with any ideas of a lateral moraine. It is very evident from the amount of weathering that this rock fall came long ago, and probably soon after the ice of the Glacial Period had retreated from Kinsman Notch.

It is now plain that most of the blocks in the river came from the sides of the original gorge, and not from the cliff, as I had formerly thought. Veins and dikes from the solid walls of the gorge can be found frequently in the loose blocks in the river, close to the places whence they were broken off. It is not always possible to say, on account of breakage, from which side of the gorge they came.

Although most of the blocks in the river came from the gorge itself, the rock fall from the cliff reaches to the very edge of the river, so it is almost certain that a number of the blocks came from the cliff. Surely the large number suggests more than just those which have fallen from the sides of the gorge.

That there was a strong earthquake in Kinsman Notch after the Glacial Period, and that this quake was the prime cause of the great rock fall, and of most of the confusion found at present in Lost River, appears likely. The movements of the joint blocks can not

be accounted for, as far as I have studied them, in any other way. The removal of a tremendous thickness of ice from the White Mountains would naturally require crustal readjustment of no small order, and hence a large earthquake or several of them would not be strange.

The evidences for an earthquake as the principal cause of the confusion in Lost River are: slickenside-like patches on a joint block over which another block had violently slipped; lateral movements among the blocks; the pell-mell manner in which the blocks are heaped; the great rock fall from the cliff, which probably came simultaneously with the shock in the river; the inadequacy of frost action to explain all of the confusion; and the elimination of the disruptive force of a moving glacier.

Although this evidence, positive and negative, does not prove that there was an earthquake in Kinsman Notch, it gives good ground for believing that there was such a shock. I have not overlooked the possibility of a local shock due to the rock fall itself. The effects observed appear too great for the vibrations a rock fall would be expected to produce.

I am greatly indebted to Dr. Philip W. Ayres, Forester of the Society for Protection of New Hampshire Forests, for guiding me to several important caverns which otherwise I must have overlooked.

ROBERT W. SAYLES

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AN ANALYSIS OF THE FACTORS CONCERNED IN THE HEREDITY OF COLOR IN TUMBLER PIGEONS¹

WHEREAS the usual methods for study of heredity serve only to show us the relation of one character to another, this work is an attempt to give our terms concerning heredity of color a real representation in the anatomy and physiology of the bird.

Some of the factors identified in these birds by breeding experiments follow: Red (*R*), Black (*B*), Intense (*I*), Spreading factor (*S*).

The *R* factor (in absence of *B*) is associ-

¹ Abstract of a paper read before the American Society of Zoologists, Cleveland, January 1, 1913.

ated with the formation of a melano-protein pigment, distinctly (pigeon) red in color, easily soluble in hot 4 per cent. sodium hydroxide. This pigment is found in reds and yellows. When *B* is present the chemical processes in the skin are profoundly changed, and a dead black exceedingly insoluble pigment is formed. *B* is completely dominant to *R*.

The effects of factor *I*, as seen macroscopically, are quantitative only. When *I* acts on red pigment there is 3.5 times more pigment formed, than when *I* is absent. Acting on black pigment *I* has a value of about 3. The physical form of the pigment is also influenced by *I*. In its absence red pigment exists as irregular masses, when it is present red pigment takes the form of small spherical granules about .4 micron in diameter, etc. On the other hand black pigment exists as spheres even in absence of *I*. When *I* is present black pigment sometimes may exist as rods.

The spreading factor *S* effects a uniform distribution of pigment throughout the barbule. When this factor is absent the pigment is aggregated in clumps, near the center of each barbule cell. This condition changes black to blue and dun to silver. The *S* factor also has an influence on granule form—and this influence varies with the presence or absence of *I*.

There is apparently a far greater mutual modification and interaction of factors in these birds than formulæ derived from external appearance alone indicate.

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A NEW WALNUT

I THINK it desirable to place before the public the fact that I have been growing for eight or ten years a walnut hybrid originating from seed of *Juglans californica* which is a hybrid between that species and some tree, probably a *Quercus* of evergreen habit. As this new form comes true from seed and may be propagated indefinitely, it is worthy of a